Surface Runoff Assessment for Nandani River Basin Using SCS-CN Method and GIS

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Abstract— Watershed is simply the geographic area through which water flows across the land and drains into a common body of water, whether a stream, river, lake, or ocean. A surface runoff (also known as overland flow) part of watershed is the flow of water occurring on the ground. Soil conservation Service (SCS) method is a simple, widely used efficient method for determining the approximant amount of runoff from a rainfall even in particular area. The runoff estimated from the SCS-CN model used to know the variation of runoff with different land use/land cover and with different soil conditions. The study area is carried out in Nandani river which is a major tributary of Yerala river, Nandani river Kadegaon Tahsil of Sangli District. The yearly rainfall data of 3 rain gauge stations (1998-2019) is collected. Landuse/Landcover map was prepared from the satellite image and soil map of study area was prepared using GIS. Landuse/Landcover map and Soil map are used to estimate curve number for SCS method. Antecedent Moisture Conditions (AMC-I, AMC-II and AMC-III) are also used for selecting suitable curve number in study area. SCS-CN method was used to determine the runoff depth distribution using Remote sensing and GIS.

Keywords: Watershed, Runoff, AMC-I, AMC-II and AMC-III), SCS, Landuse/Landcover

I. INTRODUCTION

In water resource engineering in watershed is defined as any spatial area from which runoff from precipitation is collected and drained through a common point. In arid and semi-arid regions with scarce vegetation and those disturbed by humans (urbanization).Modification of the land surface during urbanization changes the type and magnitude of runoff processes.

There are large number of methods and models in vogue for computation or estimation of runoff from a watershed. Runoff estimation becomes necessary, as the number on gauged watersheds are generally small particularly the small agricultural watershed are seldom gauged as a routine. However, runoff and its features must be known for the design of any structure either fpr storage (e.g. percolation tank) or for safe disposal (e.g. spillways) of the runoff water.

Runoff estimation is also required to know the watershed water yield, which is the governing factor for planning irrigation projects, drinking water projects and hydroelectric projects. Runoff is the result of interaction between the rainfall features and the watershed characteristics. Rainfall features are highly variable over space and time and watershed features are highly variable mainly over space. such variability precludes the possibility of developing a comprehensive theoretical base of runoff estimation. Hence, the most runoff formulas are empirical in nature, arrived at by processing long term monitored data of runoff and the causative rainfall, as well as many of the watershed features.

Runoff modeling attempts to take into account a large number of causative for estimating runoff. But many times, their complexity and the absence of well and systematically recorded time and space variant data make them difficult to utilize, in this study to produce rainfall runoff model by physiographic features like geology, geomorphology. land use/land cover, structure soil and drainage pattern using SCS-CN technique with the help of RS data and GIS technique [Abhijeet zende et,al.2012,R.Amrutha 2009].

A. *Objective*

Evaluation of hydrological parameter, such as soils, land use/land cover, drainage, geomorphology with the help of GIS, The estimation of rainfall-runoff model value using combination of SCS model.

II. STUDY AREA AND METHOD

The present study is carried out in Nandani river which is a major tributary of Yerala river. Nandani river flows in between Khatav tahsil, Satar and Kadegaon Tahsil Sangli District. The study area is located on 17°13´14´´ N to 17°33´52´´ N latitudes and 74°14´35´´ to 74°25´21´´ longitude. It is bounded by Upale Vangi at north, Kherade Bk at east, Tondoli at the south-east, Belavade at the south direction and Yede at the west. The watershed experiences tropical monsoon climate with normal temperature, humidity and evaporation throughout the year. The monsoon season in the watershed is from June to December. The rainfall occurrence during July and August is comparatively more than rest of the year and significant amount of runoff occurs in the river basin. Average annual rainfall is 600 mm.

III. METHODOLOGY

In this study, survey of India topographical sheet no E43O06, E43O07, E43O08 on the scale of on the scale of 1:50000 were used to fixed the watershed boundary. Drainage and contour Remote sensing data of IRS P6-LISS 3 sensors, on the scale of 1:50000 for layout of land use and land cover map. Hydrological soil map, hydrological soil group was prepared according to soil properties and type of land use and land cover for the assessment of runoff by river basin. Yearly rainfall data from 3 rain gauge stations for the year of 1998 to 2019 (21years).data were used to calculate the runoff using SCS-CN method.

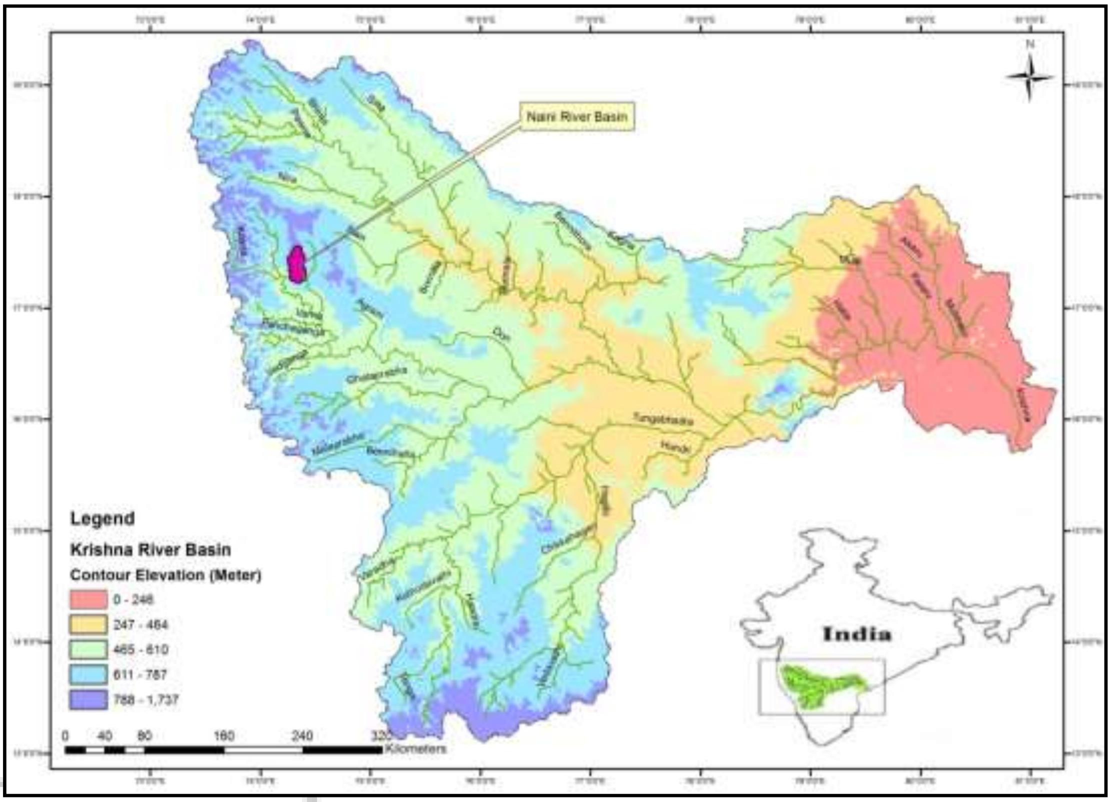

Fig. 1: Location Map of Nandani River Basin

A. *SCS Curve Number Method*

The most commonly used empirical method is the Soil Conservation Service Curve Number (SCS-CN) method to estimate the direct runoff from a watershed (USDA, 1972). The SCS-CN method explaining the water balance equation can be expressed as below (Mishra and Singh 2003):

$$P = I_a + F + Q \quad (1)$$

$$\frac{Q}{P - I_a} = \frac{F}{A} \quad (2)$$

$$I_a = \lambda S \quad (3)$$

where, P is the total precipitation (mm); Q the direct runoff (mm), F the cumulative infiltration (mm), Ia is the initial abstraction (mm); S the potential maximum retention (mm) and the initial abstraction coefficient (0.3), and includes surface storage, interception, and infiltration prior to runoff in the watershed and empirical relation was developed for the term Ia and it is given by,

$$Q = \frac{(P - I_a 2)^2}{(P - 2I_a + S)} \quad (4)$$

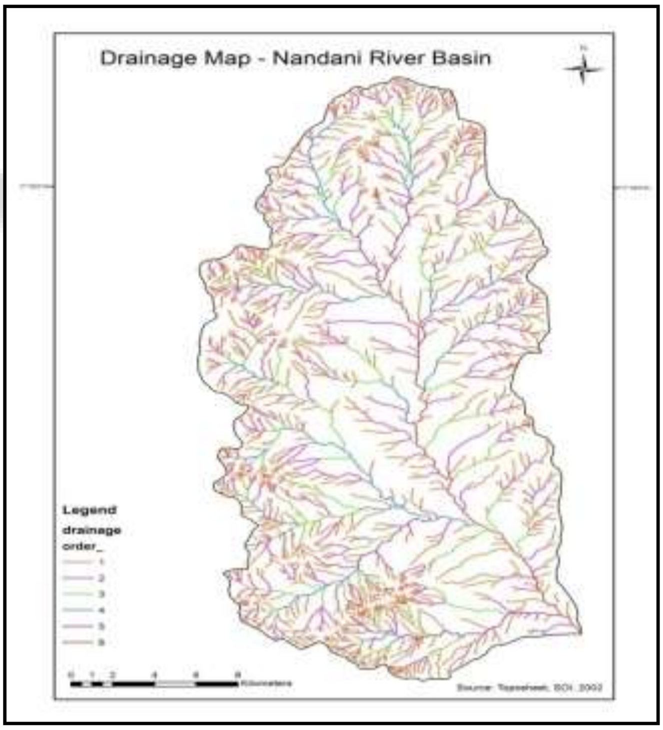

Fig. 2: Drainage network of Nandani River Basin

Which is valid for P, Ia. Otherwise, Q = 0. For a constant value of Ia (O.3S), S can be determined from the P-Q data. In practice S is derived from a mapping equation expresses in terms of the curve number (CN).

$$S = \frac{25400}{CN} + 254 \quad (5)$$

The CN (dimensionless number ranging from 0 to 100) is determined from a table, based on land-cover, HSG and AMC. HSG is expressed in terms of four groups (A, B, C and D), according to the soil after prolonged wetting. AMC is expressed in three levels (1, 2 and 3), according to rainfall limits dormant and growing seasons. Although SCS method is originally designed for use in watershed of 15 km^2, it has been modified for application to larger watersheds by weighing curve numbers with respect to watersheds/landcover area. In this study, the curve numbers are weighted with respect to the micro-watershed are weighed with respect to the micro-watershed area (generally < 5 km^2) using the following equation:

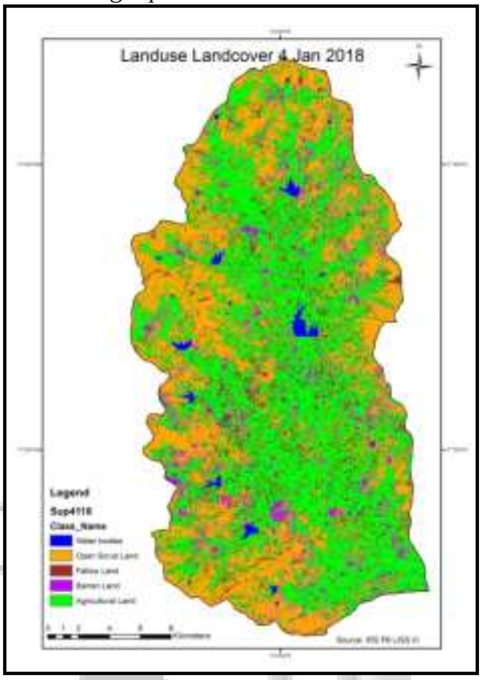

Fig. 3: Landuse/Landcover Map Jan 2018

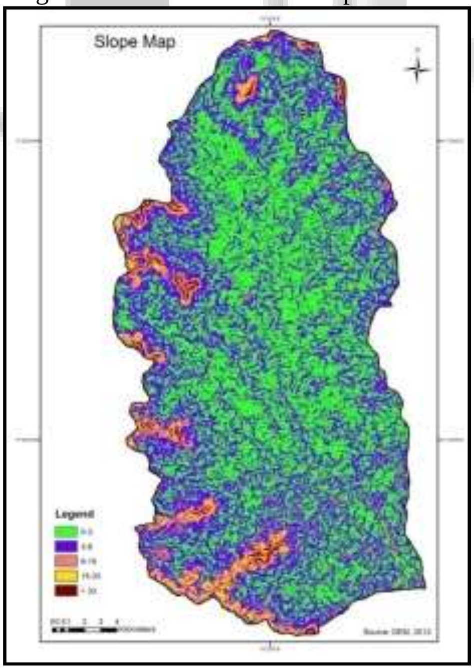

Fig. 4: Slope Map of Nandani River Basin

$$CNW = \frac{\Sigma(CN_i i * A_i)}{A} \quad (6)$$

where, CNw is the weighted curve number; CNi is the curve number from 1 to any number N; Ai is the area with curve number Cni ; and A the total area of the micro-watershed. The SCS curve number is a function of the ability of soils to allow infiltration of water with respect to land use/land cover and antecedent soil moisture condition (AMC). According to U.S soil conservation service soils are divided into four hydrologic soil groups such as group A, B, C & D with respect to rate of runoff potential and final infiltration rate.

B. Hydrological Soil Group

Soil properties greatly influence the amount of runoff. In the SCS method, these properties are represented by a hydrological parameter: the minimum rate of infiltration obtained for a bare soil after prolonged wetting. The influence of both the soil's surface condition (infiltration rate) and its horizon (transmission rate) are thereby included. This parameter, which indicates a soil's runoff potential, is the qualitative basis of the classification of all soils into four groups. The Hydrological Soil Groups, as defined in the SCS-CN method.

1) Group A – soil having high infiltration rates even when thoroughly wetted and a high rate of water transmission. Examples are deep,well excessively Drained sand and gravels.
2) Group B- Soils having moderate infiltration rates when thoroughly wetted and a moderate Rate of water transmission.Examples are moderately deep to deep,moderately well to well drained soils with moderately fine to moderately coarse textures.
3) Group C – Soils having low infiltration rates when thoroughly wetted and a low rate of water transmission. Examples are soils with a layer that impedes the downword movement of water or soils of moderately fine to fine texture.
4) Group D – Soils having very low infiltration rates when thoroughly wetted and a very low rate of water transmission. Examples are clayey soils with a high swelling potential, soils with a permanently high water table, soils with a clay pan or clay layer at or near the surface, or shallow soils over nearly impervious material.

C. Antecedent Soil Moisture Condition (AMC)

The soil moisture condition in the drainage basin before runoff occurs is another important factor influencing the final CN value. In the curve number method, the soil moisture condition is classified in to three antecedent moisture condition (AMC) Classes (Table 1). AMC I- The soils in the drainage basin are practically dry (i.e. the soil moisture content is at wilting point); AMC II – Average condition; AMC III – The soil in the drainage basins the practically saturated from antecedent rainfalls(i.e. the soil moisture content is at field capacity)

Hydrologic Soil Group	Type Of Soil Runoff	Potential	Final Infiltration Rate (mm/Hr)	Distribution (%)	Remarks
Group A	A Deep, well drained sands and gravels	Low	>7.5	4.73	High rate of water transmission
Group B	Moderately deep, well drained with moderately fine to coarse	Moderate	3.8-7.5	25.54	Moderate rate of water transmission
Group C	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Moderate	1.3 – 3.8	52.04	Moderate rate of water transmission
Group D	Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high water table	High	< 1.3	18.69	Moderate rate of water transmission

Table 1: Hydrological soil group classification

D. *Area Weighted Curve Number*

Arc GIS 9.3 was used to all the superimposed layer of HSG, soil and land use-land cover. PAT (polygon attribute table) to calculate the whole area weighted curve number and calculate the AMC 2 and result obtained (Table 2)

Sr. No.	Land use	Soil Type	Area in km^2	CN	% area	% area * CN	Weighted curve number
1	Agricultural	B	122	81	70.93	5745.35	AMC I-30.14 AMC II-49.61 AMCIII-69.74
		C	97	82	56.40	4624.42	
		D	79	94	45.93	4317.44	
2	Settlement/fallow land	B	8	78	4.65	362.791	
		C	14	84	8.14	683.721	
		D	15	88	8.72	767.442	
3	Natural Vegetation	C	12	79	6.98	551.163	
		D	18	80	10.47	837.209	
4	Open scrub Land	B	25	85	14.53	1235.47	
		C	30	84	17.44	1465.12	
		D	34	89	19.77	1759.3	
5	Barren Land	D	18	86	10.47	900	
6	Waterbodies	-	20	100	11.63	1162.79	

Table 2: Weighted curve Number for Nandani River Basin (for AMC 2)

E. *Estimation of Rain Fall and Runoff*

Area weighted curve number and yearly rainfall database from 1998 to 2019 (for 21 years) of nandani river basin were filled into SCS formula and the result are found from yearly rainfall results are found. The rainfall and runoff values for the 21years are given below (Table 3.)

Year	Rainfall (mm)	Runoff (mm)	Runoff (mm^3)	Year	Rainfall (mm)	Runoff (mm)	Runoff (mm^3)
1998	356	303.75	63.02	2009	758	702.69	145.79
1999	368	315.57	65.47	2010	635	580.24	120.38
2000	401	348.13	72.23	2011	453.3	399.85	82.96
2001	425	371.85	77.15	2012	419.45	366.36	76.01
2002	388.04	335.29	69.56	2013	549.62	494.22	102.54
2003	288.23	237.65	49.30	2014	627.65	572.5	118.78
2004	736	680.77	141.24	2015	491.75	437.45	90.76
2005	920	864.18	179.29	2016	539.82	485.62	100.75
2006	1038.4	981.91	203.72	2017	628.15	573.42	118.97
2007	820	764.47	158.60	2018	551.9	497.6429	103.25
2008	710	654.88	135.87	2019	1028.06	971.99	201.66

Table 3: Yearly Runoff for Nandani River Basin

IV. RESULTS AND DISCUSSION

The quantity and amount of runoffs depends on the characteristics of the field and meteorological conditions and estimating runoffs. In addition to the quantity of precipitation, which is one of the most important hydrological characteristics of estimating runoff quantity, the type of soil, land usability and flora, the hydrological condition of the area and, also, the former moisture of the soil are important factors that have an important influence on determining the amount of runoff. The hydrologic soil group which signifies the soil type, characteristics, and its infiltration capacity acts important role while measuring the runoff potential. The hydrologic soil category of 'B','C' and 'D' were explained with by agricultural land 57.75% area of fallow land,6.59% area covers open scrub land17.24% and remaining 18.92% of the area is covers by other such as water body and barren land. In general, the fallow land among the different land cover types acts the main role for the direct surface runoff. Were explained with reference to remote sensing data and other secondary data in this study area. The hydrologic soil group and land use the curve number was allotted according to Scand resulting the antecedent moisture conditions values are

AMC 1, AMC 2 and AMC 3. The yearly runoff evaluated in both mm^3 and mm and has fluctuated from the year of 1998 to 2003 and suddenly increased between the years of 2004 to 2010 and gradually decreases and increases from the year 1998 to 2019.The trend line for the average rainfall is in the straight line for indicates that rainfall has decreased from the year 1998 to 2015. The result of the rainfall runoff trend line indicates that there is high runoff taking place comparatively. It is reasonably more runoff in this area and further it can be controlled by converting fallow land into agricultural land since it occupies 57.75% of the total land area.

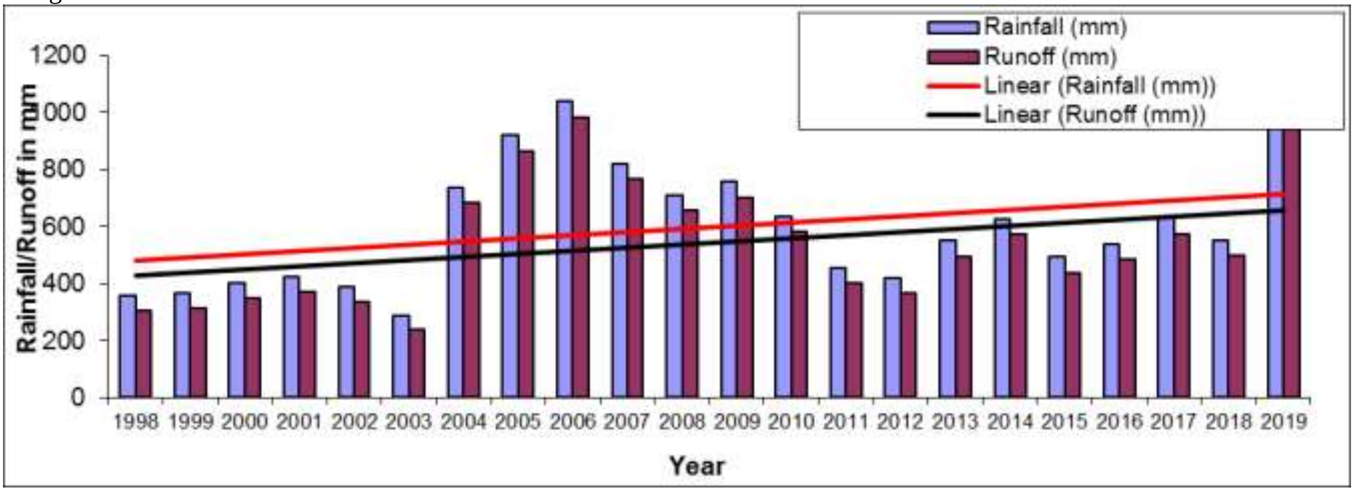

Fig. 6: Average Rainfall vs Average Runoff

V. Conclusion

Generally in carrying out research projects on the issues concerning flood , due to lack of sufficient statistics and information in watered fields, hydrological data are insufficient for determination of design and process of water resources schemes. The great use of RS data for the evaluation of important hydrological parameters, like soils, land use/land cover, drainage, geomorphology etc.The estimation of runoff value using combination of SCS model and remote sensing gives the good accuracy within time. GIS is an efficient tool provides the adequate input file for the preparation of the SCS curve number model in watershed management. The analysis often extended further to guage the effect of land use variations, after Progresses within the watershed, on the rainfall-runoff relationship. Water irrigation are done to the related agricultural land and other utility purposes by evaluating the difference in annual runoff.

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References

[1] Abhijit M. Zende, R. Nagarajan, K. R. Atal, (2012); Analysis of Surface Runoff for Yerala River basin using SCS-CN and GIS, In ternational Journal of Geomatics and Geosciences, Vol. 4, No.3, pp. 508-516.
[2] D. Ramakrishnan, A.Bandyopadhyay, K .N Kusuma (2009), SCS-CN and GIS based approach for identifying potential water harvesting sites in the Kali watershed, Mahi River Basin, India; J. Earth Syst. Sci. 118 No.4, pp: 355 -363.
[3] Ali panahi (2013) Evaluating SCS-CN Method in Estimating the Amount of Runoff in Soofi Chay basin Using GIS. Life Sci J;10(5s):pp.271-277.
[4] Hand Book of Hydrology (1972), Soil and Water Conservation Department, Ministry of Agriculture, New Delhi.
[5] R. Amutha, P. Porchelvan (2009), Estimation of surface runoff in Malatter Sub-watershed using SCSCN method, J. Indian Society Remote Sensing (June), 37, pp. 291–304.
[6] Tejram Nayak, Verma M.K, Hema Bindu.S (2012), SCS curve number method in Narmada basin International Journal of Geomatics and Geosciences Volume 3, No 1, pp. 271-275 .
[7] G. B. Geena and P.N. Ballukraya (2011), Estimation of runoff for Red hills watershed using SCS method and GIS. Department of Applied Geology, University of Madras, Maraimalai Campus, Guindy, Chennai, Vol. 4 No. 8, pp.899-902.
[8] Shwetha G, B. Maheshwara Babu, B. S. Polisgowdar, G. V. Srinivas Reddy & U. K. Shanwad (2015), Estimation Of Surface Runoff In Timmapur , Watershed Using Scs-Cn Method. International Journal Of Agricultural Science And Research (Ijasr), Vol. 5, Issue 6, pp.1-8.
[9] P.Sundar Kumar, Dr.M.J.Ratna Kanth Babu,Dr. T.V.Praveen,Venkata kumar.vagolu (2010) Analysis of the Runoff for Watershed Using SCS-CN Method and Geographic Information Systems, International Journal of Engineering Science and Technology, Vol. 2(8), pp.3947-3954.
[10] Tejram Nayak, Verma M.K, Hema Bindu (2012). SCS curve number method in Narmada basin. International Journal of Geomatics and Geosciences Volume 3, No 1, pp. 845-853.

